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Emotion-Cognition-Body Interconnected Dynamism : Multidisciplinary and Neuroscientific Perspectives

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情動・認知・身体のダイナミズム
――学際的・神経科学的観点から――

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Abstract :

This paper investigates the new and better understanding of emotion, cognition, body, and their organically interconnectedness from multidisciplinary perspectives. First, perspectives from such domains as physics, sociobiology, psychopathology, cognitive science, neurobiology, educational psychology, neuropsychology, neurology, behavioral economics, kansei engineering, developmental psychology, evolution science, artificial intelligence, and SLA (second language acquisition) are introduced and argued. Second, neuroscientific facts are provided and state-of-the-art findings are discussed. A plethora of theories, cases, quotes, and information sources are utilized to support and to explicitate the active, dynamic, and organic view of emotion, cognition, and body. Finally, it concludes with future prospects toward better educational theory and practice with special focus on foreign language acquisition.

要旨：本論では学際的観点から、情動・認知・身体とその有機的に不可分の関係のより良い理解を考察する。まず、物理学・社会生物学・精神病理学・認知科学・神経生物学・教育心理学・神経心理学・神経学・行動経済学・感性工学・発達心理学・進化論・人口知性・第二言語習得といった諸分野の関連理論や先行研究を紹介・議論する。次に、神経科学的事実が説明され、脳科学の最新の知見が紹介される。能動的・動的・有機的な情動観が、数多くの理論・実例・引用・情報源を通して支持され、明示化される。最後に、より良い教育理論や実践に向けた展望が、外国語学習に着目して提起される。

Key words : Emotion, Cognition, Body, Multidisciplinarity, Neuroscience

1. Introduction

A plethora of recent scientific investigations validate, corroborate, and even extend the philosophical and early psychological insights and discussions on the intertwined nature of cognition, emotion, and body. This paper presents theories, statements, and lines of facts to show the new and better understanding of emotion, cognition, body, and their organically interconnectedness from a

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wide range of academic fields.

2. Multidisciplinary perspectives : Physics, sociobiology, emotional intelligence, psychopathology, cognitive science

A renowned theoretical physicist David Bohm equates the process of thought with the active response of memory and argues that its content is not pure intellectual cognition but "the conjunction of the image with its feeling, which (along with the intellectual content and the physical reaction) constitutes the totality of the judgment as to whether what is remembered is good or bad, desirable or not" (Bohm, 1980, p.64).[1)]

Edward Osborne Wilson, the father of sociobiology, defines emotion as "the modification of neural activity that animates and focuses mental activity (Wilson, 1998, p.123)" and explains that "without the stimulus and guidance of emotion, rational thought slows and disintegrates. The rational mind does not float above the irrational ; it cannot free itself to engage in pure reason" (ibid.).

Daniel Goleman, an influential psychologist who promulgated the concept of *emotional intelligence,* eloquently describes that "in the dance of feeling and thought the emotional faculty guides our moment-to-moment decisions, working hand-in-hand with the rational mind, enabling－or disabling－thought itself" (Goleman, 1995, p.28). He further declares that "the old paradigm held an ideal of reason freed of the pull of emotion. The new paradigm urges us to harmonize head and heart. To do that well in our lives means we must first understand more exactly what it means to use emotion intelligently" (ibid., p.29).

In the field of psychopathology, Karl Jaspers, who is famous both as a distinguished psychiatrist and as a great figure in existentialism, gives an exhaustive classification on emotion, demonstrating the multifacetedness and transdisciplinarity of emotion (Jaspers, 1913/1997, pp.108-117 ; for its value in modern psychopathology, see Rosfort & Stanghellini, 2014). Carroll Ellis Izard, a psychologist who is famous for differential emotions theory, defines emotion as "a complex concept that has neurophysiological, neuromuscular, and phenomenological aspects" (Izard, 1972, p.135), clearly showing the multileveled involvement of body and consciousness in emotion. His view of emotion is applied to psychopathology, indicating its pragmatic value (Kleinmuntz, 1980).

In the field of cognitive science, Steven Pinker states that "emotion mobilizes the mind and body to meet one of the challenges of living and reproducing in the cognitive niche" (Pinker, 1997, p.374). More recently, a post-cognitivist revolutionary hypothesis of *embodied cognition* is developed based on ecological psychology (Shapiro, 2011), in which the source of cognition is no longer the complex internal mental representations in the brain but the real time interplay of task-specific resources distributed across the brain, the body, and the environment, coupled together via our perceptual systems (Wilson & Golonka, 2013). Embodied cognition provides a new paradigm for inquiry not only for cognitive science itself but also for education (Ionescu & Vasc, 2014), SLA (At-

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1) One of the remarkable predecessors of D. Bohm in the field of physics is Ernst Mach (1838-1916), who had a profound influence on later important philosophical movements such as logical positivism and pragmatism. According to Mach, "our body, like every other, is part of the world of sense ; the boundary-line between the physical and the psychical is solely practical and conventional" (Mach, 1886/1914, p.311) and "everything is reducible to the discovery, selection, and emphasis of the determinative sensational elements" (ibid., p.325).

kinson, 2010), and language teaching (Buccino & Mezzadri, 2015).

3. Multidisciplinary perspectives： Neurobiology, educational psychology, neuropsychology, neurology, behavioral economics, usability engineering

In the field of neurobiology, Antonio Damasio defines emotion as “the combination of a mental evaluative process, simple or complex, with dispositional responses to that process, mostly toward the body proper, resulting in an emotional body state, but also toward the brain itself (neurotransmitter nuclei in brain stem), resulting in additional mental changes” (Damasio, 1994, p.139). Based on ample clinical evidences, he criticized traditional view to regard decision making as the result of high-reason and proposed *somatic-marker hypothesis,* a biologically valid account of decision making which posits that emotions and feelings are enmeshed in cognitive networks and that human reason developed only with the guiding force of emotions and feelings (Damasio, 1994, Chapter 8).

Educational psychologist Mary Helen Immordino-Yang, collaborating with Antonio Damasio, applies the neurobiological findings to education and succinctly states that “the more educators come to understand the nature of the relationship between emotion and cognition, the better they may be able to leverage this relationship in the design of learning environments” (Immordino-Yang & Damasio, 2007, p.9).

In the field of neuropsychology, Joseph LeDoux reviews ample emotion research and argues that emotion precedes cognition evolutionarily and is related to neural “circuits that instantiate functions that allow organisms to survive and thrive by detecting and responding to challenges and opportunities” (LeDoux, 2012, p.654). Antonio Damasio and Joseph LeDoux are also influential and are famous figures whose works often cited in the fields of second language acquisition and applied linguistics (e.g., Schumann, 1997).

In the field of neurology, Robert A. Burton asserts that “disembodied thought is not a physiological option. Neither is a purely rational mind free from bodily and mental sensations and perceptions” (Burton, 2008, p.127). A cognitive neuroscientist Jeremy R. Gray laments the traditional tendency to treat emotion as the nemesis of self-control and acknowledges that “emotional states can enhance high-level cognition, and can modulate the neural mechanisms that support cognitive control” (Gray, 2004, p.46).

In the field of behavioral economics, a Nobel laureate psychologist Daniel Kahneman introduces two mutually influencing cognitive systems： System 1, which is capable of fast, intuitive, emotional, and automatic processing, and System 2, which is capable of slow, deliberate, intellectual, and effortful contemplation. Contrary to what the majority of people would expect, System 2 plays a limited role in decision making. The command center of most decision is the subconscious System 1. In most cases, what System 2 does is no more than the *ex post facto* approval of the decision by System 2. Although they were designed to be fictitious metaphorical characters rather than ontological entities (Kahneman, 2011, pp.29-30), it has been proven that each system has their own interrelated neural substratal systems (Burns & Bechara, 2007).

In the field of usability engineering/*kansei* engineering,[2)] Donald Arthur Norman, the pro-

2）Kansei engineering（感性工学）, also known as affective engineering, is a new branch of engineering originate in Japan (cf. Nagamachi, 2011). Kansei（感性）is a loanword from Japanese language whose meaning includes sensitivity, sensibility, and sensitiveness, sense, feeling, image, affection, emotion, want, and need (ibid., p.2).

pounder of the influential concept *emotional design,* argues that “everything you do has both a cognitive and an affective component－cognitive to assign meaning, affective to assign value. You cannot escape affect：it is always there. More important, the affective state, whether positive or negative affect, changes how we think” (Norman, 2004, p.25). His concept of the *emotional design* has been widely applied to such practical fields as product development, marketing, and designing.

4. Multidisciplinary perspectives：Psychiatry, developmental psychology, evolution theory, affective science, artificial intelligence, second language acquisition

Psychiatrist Luc Ciompi (1997/2005), the proposer of the sophisticated *fraktalen Affektlogik* [fractal affect-logic] framework, revisits a plethora of mental phenomena and persuasively shows how inevitable emotion is for various major cognitive processes (cf. Kanazawa, 2016, p.25, Table 1).

Terms and concepts similar to *affect-logic* have been coined or discovered in different academic domains via different arguments and evidences. They include philosophy of science (e.g., *hot cognition*；Thagard, 2006), educational psychology (e.g., *emotional thought*；Immordino-Yang, 2016), and developmental psychology (e.g., Vygotskian *переживание*；*perezhivanie*；*emotional experience*；cf. Blunden, 2016).

Developmental psychologist Heinz Werner proposes that each mental phenomenon is *cognitive microgenesis,* the immediate dynamic self-organizing process on a brief here-and-now micro scale of a percept, a thought, an image, or an expression (Werner, 1956；cf. Buckingham, 1991；Brown, 2015). Only the fully developed *final gestalt* of the dynamic microdevelopmental process becomes a conscious experience on which cognition can shed light (Conrad, 1954). The vague experiences at the early stages of the dynamic process are none other than emotion (Yamadori, 2008).

From the perspective of evolution, Jaak Panksepp, the founder of the academic domain called *affective neuroscience,* notes that “many of the ancient, evolutionarily derived brain systems all mammals share still serve as the foundations for the deeply experienced affective proclivities of the human mind. Such ancient brain functions evolved long before the emergence of the human neocortex with its vast cognitive skills” (Panksepp, 1998, p.4). Panksepp’s explanation is complemented with the famous *“triune brain”* model of cerebral evolution (MacLean, 1990). According to the triune brain model, the limbic system, which is involved in emotional behavior and the subjective experience of emotion (p.247), is layered beneath the neocortex, which is the seat of higher cognition that only humans are reported to have (for its pictorial image, see Barrett, 2017, p.82).[3] Limbic system phylogenetically and ontogenetically precedes neocortex and has a strong connection to the so-called reptilian brain, which is allegedly the seat of survival mechanism and biological homeostasis control system.[4] Recent biological findings are in accordance with the triune view；emotion is reported to be a limbic adaptation to homeostatic demands (Rhodes & Rhodes, 2017) and ancestral

3）The triune brain model is so persuasive and intriguing that it has been cited and extended by such widely known figures as Carl Sagan (1977, pp.57-58) and Daniel Goleman (1995). It was even featured in a university English reading textbook in Japan (Shimaoka & Berman, 2015, pp.34-37). However, it is also noteworthy that positing just “three separately evolved and to some degree independently functioning cognitive systems” (Sagan, 1977, p.266) is criticized in the state-of-the-art theories of emotion (Barrett, 2017；Kanazawa, 2018).

4）The reptilian brain would correspond to the arousal structures in the classical conditioning terms (cf. Dykman, 1965, p.278).

emotional systems underlie human personality structures and intelligence (Montag & Panksepp, 2017). To sum up, emotion and cognition are evolutionary continuum, the former providing the basis for the latter in terms of both ontogeny and phylogeny.

Luiz Pessoa's (2015) one of the latest *précis* of neuroimaging findings elucidates how neural substrata of emotional processing and cognitive processing are intertwined with each other, contrary to the traditional view of Cartesian dichotomous localization. He asserts that the impact of emotion is wide-ranging and emotion is interlocked with perception, cognition, motivation, and action in the form of functionally integrated system (Pessoa, 2017, p.357). Moreover, it has been empirically proven that not only at the conscious level but also at the unconscious level does emotional processing interact with cognitive mechanisms underlying language comprehension (cf. Wu & Thierry, 2012). Furthermore, it has been proposed that consciousness, without which cognition cannot emerge, is shaped partly by emotional system (Schutter & Van Honk, 2004).

In the field of artificial intelligence (AI) and neural computation, a recently developed algorithms of artificial neural processing and network is based on the theory of *emotional brain* (LeDoux, 1996) and is named *brain emotional learning* (BEL), indicating the significance of emotion in the architecture of cognition, presumably beyond that of organic beings (Lotfi, Khazaei, & Khazaei, in press).

In the field of SLA, Danuta Gabryś-Barker (2010) reviews neuro-psycholinguistic empirical evidences and shows that language processing and language learning are not devoid of emotion, providing study proposals for further investigation of emotion and language processing in L2 settings. Michael Sharwood Smith (2017 b) succinctly summarizes that "affective processing is so intimately involved in cognitive processing that it makes no sense to treat affect and cognition as areas that should be investigated in complete separation from one another" (p.44).

These multifarious remarks from multidisciplinary academic spectrums, although being merely the tips of the iceburg far from being an exhaustive list, exemplify how cognition, emotion, and body are inseparably intertwined with one another.

5. Neuroscientific perspectives

In the 17th century, Francis Bacon, the father of scientific method (viz., induction), clearly stated that memory, or retaining of knowledge in general, is one of the major parts of Reason (i.e., cognition; Bacon, 1605/1893, §XV, 1-2). Memory, one of the major components of cognition, is known to play a crucial role in learning (Stevick, 1999). In this subsection, neuroanatomical and neurofunctional evidences of emotion-cognition dynamism are reviewed from the perspective of memory theories and studies. Damasio (1998) succinctly states that emotion and memory "are so closely coupled that one cannot fully understand the latter without the former" (p.84). Pioneering study on this field focused on the effect of emotional mood on memory (Bower, 1981). In the 21st century, Talmi and colleagues (2007; 2012) have found that emotional words, pictures, and stories have mnemonic advantages regarding both recall memory and recognition memory (which is named Emotionally Enhanced Memory; or EEM). It has even been empirically proven that EEM transfers prospectively; emotion can enhance memory formation for unrelated information in the future (Tambini et al., 2017).

Neuroscientific studies provide ample evidences and rationales for EEM. The neural substrate widely acknowledged to play a central role in emotional processing is amygdala, one of the key structures of limbic system found deep inside the temporal lobe adjacent to the hippocampus (Squire & Kandel, 2009 ; Figure 1).

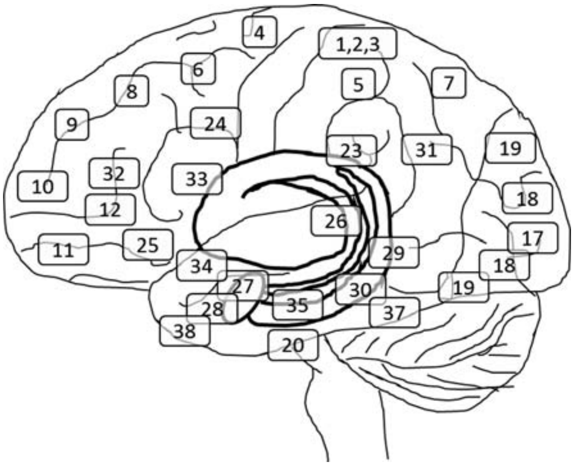

Figure 1 Anatomical locations of amygdala and hippocampus are depicted with reference to the numbers of the mid-sagittal view of Broadmann areas of the cerebral cortex. They are located in the subcortical limbic system near 27, 28, 34, and 35. The figure was drawn by the author.

The functions of amygdala and hippocampus are different : the former supporting nondeclarative emotional memories regardless of their emotional valence (LaBar & Cabeza, 2006 ; Yang et al., 2002) whereas the latter supporting the short-term memory (Hannula, Ryan, & Warren, 2017), formation of semantic memory (Manns & Eichenbaum, 2006), episodic memory (Sheldon & Levine, 2016), spatio-temporal memory (Nielson et al., 2015), recognition memory (Merkow, Burke, & Kahana, 2015), working memory (Moscovitch et al., 2016), consolidation of declarative memory (Antony & Paller, 2017), memory integration (Schlichting & Preston, 2017), linguistic processing (Piai et al., 2016), communicative language use (Duff & Brown-Schmidt, 2017), attention (Aly & Turk-Browne, 2017), holistic recollection utilizing event engrams (Horner et al., 2015), future prediction (Buckner, 2010), and even cognition in general (Lazarov & Hollands, 2016).

Despite the independence of the two systems, it is known that they regularly work coordinately via connected activation (Davis & Whalen, 2001 ; Phelps, 2004 ; Blakemore & Frith, 2005 ; Ono, 2012) and both of them have dynamic networks with cortical areas including prefrontal cortex and fronto-parietal network, which are identified as the major neural substrates for higher cognition and intelligence (Uylings, 2000 ; Hervig, 2017 ; Inhoff & Ranganath, 2017 ; Burgos-Robles et al., 2017 ; Dixon et al., in press ; Westerhausen et al., in press). In accord with the amygdala-hippocampus-cortex interlocked view, amygdala has found to play crucial roles not only in emotional process *sui generis* but also in motivation (Tye & Janak, 2007), anxiety control (Tye et al., 2011), elicited or default approach (Harrison, Hurlemann, & Adolphs, 2015), appetitive learning (Kolada et al., 2017), control of behavioral engagement (Paré & Quirk, 2017), cataplexy (Snow et al., in press), implicit memory (Dolan, 2002), explicit memory (LeDoux, 2007), long-term memory (McGaugh et al., 1996), gist memory (Adolphs et al., 2005), endogenous memory prioritization processes with or without emotional input (Inman et al., in press), valence processing (Correia & Goosens, 2016), perception (Anderson & Phelps, 2001), attention, and even higher cognitions such as executive function in working memory (Schaefer & Gray, 2007), social recognition memory

(Tanimizu et al., 2017), social behavior (Phelps & LeDoux, 2005), aesthetic judgments (Jacobs & Cornelissen, 2017), moral cognition (Casebeer & Churchland, 2003), and human bonding (Atzil et al., 2017).[5)]

According to LeDoux's (2007) detailed explanation of the neural mechanism, outputs of the amygdala "lead to the release of hormones and/or neuromodulators in the brain that then alter cognitive processing in cortical areas. For example, explicit memories about emotional situations are enhanced via amygdala outputs that ultimately affect the hippocampus" (p.R 873). In such a case when amygdala is dysfunctional (e.g., for patients with Alzheimer's disease), the EEM is reported to decrease (Kensinger, 2006) even when their emotional processing and recognition of familiarity are intact (Kalenzaga et al., 2015).[6)] In short, emotion, memory, and higher intellectual cognition are no less reciprocally interrelated than amygdala, hippocampus, and cortical areas are.[7)]

4. Conclusion and prospects

This paper introduced, discussed, and demonstrated a wide variety of theories, insights, and lines of facts. As a result, it is more than legitimate to conclude that emotion, cognition, and body are indeed intertwined with one another organically, in contrast to the traditional views to draw fundamental lines among them, and negating the understanding that emotion and cognition are in a trade-off relationship with each other. What is needed for the cultivation of cognition (i.e., education) is not to ward off emotion but to seek how one can "weave" cognition and emotion in an optimal and elegant manner. As was introduced above, the importance of emotional factors in cognitive development is becoming more and more noticed in various fields, both in academia and in classrooms. It is also the case with applied linguistics, with growing interest in motivation and emotion (cf. Dörnyei & Ushioda, 2011 ; Dewaele, 2011). It is, however, needed to proceed further, to go beyond the modular view in which affective factors influence cognitive factors in a modular manner. In terms of organic dynamism of emotion-cognition-body, it is desired to grasp the transient micro-level emotions which are too subtle to become aware, self-report, and analyze (cf. Kanazawa, 2016).

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5) In a similar vein, hippocampus *per se* is known to be involved not only in memory and cognition *sui generis* but also in emotionally charged cognitions (Anacker & Hen, 2017).

6) The function of amygdala, however, may be compensated by other adjacent regions if amygdala lesions were acquired earlier in life (Bach et al., 2011).

7) It cannot be denied that the statement was rather oversimplified. It is more accurate to state that amygdala-driven system (cf. Yakovlev circuit) and hippocampus-driven system (cf. Papez circuit) are interconnected. In addition, recent studies have found other cortical structures supporting emotion and cognition. For example, anterior cingulate cortex (ACC) is reported to be involved in error detection and its top-down correction, which require regulation of both cognitive and emotional processing (Bush, Luu, & Posner, 2000 ; Stevens, Hurley, & Taber, 2011), ventromedial prefrontal cortex (vmPFC) is for the cognition-emotion connection (Roy, Shohamy, & Wager, 2012) and understanding the emotions of others (Spunt & Adolphs, in press), medial and lateral prefrontal cortex (PFC) for integration of higher-order cognition and affect (Dum, Levinthal, & Strick, 2016 ; Gray, Braver, & Raichle, 2002 ; working memory capacity is also attributed to the function of the lateral PFC ; Minamoto, Tsubomi, & Osaka, 2017), insula cortex and its mirror neurons for affective empathy (Rizzolatti, 2005 ; Eres et al., 2015), and many other neural substrates (Barrett et al., 2007). A recent neurofunctional model distinguishes "affect system" from "effector system" and explicates the complex neuroanatomical emotional systems (i.e., The Quartet Theory of Human Emotions ; cf. Koelsch et al., 2015). One of the up-to-date models of emotion named a Network Model of the Emotional Brain proposes that emotion is best described as functionally integrated systems of cortex-subcortex and cortex-amygdala rather than in terms of a circumscribed set of cortical and subcortical brain regions (Pessoa, 2017). Notwithstanding, it still holds true that emotional, cognitive, and kinesthetic systems are intertwined with one another, be it domain-specifically or nonspecifically.

Correspondingly, new cognitive models on foreign language acquisition such as MOGUL (Sharwood Smith, 2017 a) and Emotion-Involved Processing Hypothesis (Kanazawa, 2017) have been proposed recently, with emerging attempts of pedagogical application of language learning classrooms (Oyama, 2018). It is hoped that such new attempts will be encouraged, facilitated, investigated, and studied, with accumulating evidences. Needless to say, making theories and practices based on fragile evidences is no more to be avoided than building a castle on sand. May the lines of facts and the ample sources organized and cited in the present and the preceding papers be utilized as a small portion of the solid ground for better theories, practices, and last but not least, erudite outlook of the readers.

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